

SPECIFICATION

TITLE OF THE INVENTION

A GLASS SUBSTRATE OF DISK FOR RECORDING INFORMATION, A
DISK FOR RECORDING INFORMATION, AND A DISK DEVICE FOR
RECORDING INFORMATION

5 This is a continuation of application Serial No.
08/888,124, filed July 3, 1997.

BACKGROUND OF THE INVENTION

10 The present invention relates to a glass substrate in
the form of a disk for recording information, and more
particularly, to a glass substrate in the form of a disk,
for use in a fixed type magnetic disk recorder and in a
photomagnetic disk apparatus, which is superior in chemical
stability and thermal stability at a high temperature and in
flatness. The invention also relates to a disk for
15 recording information and a disk apparatus for recording
information using the glass substrate.

20 Magnetic disks and photomagnetic disks are used at the
present time as media for recording information in large
scale computers and personal computers. Currently,
substantial advances have been made in increasing the
recording density and decreasing the size and weight of the
media for recording information. In the field of the
magnetic disk apparatus, magnetic disk substrates of small

size, such as disks having diameters of 2.5 inches, 1.8 inches and 1.3 inches, have been developed. Not only the diameter, but the thickness of the disk substrate as well has been decreased. Accordingly, a substrate having a
5 larger mechanical strength than ever is required.

Furthermore, the levitating amount of the disk on the head has been decreased, and improvement in the flatness of the disk, which is capable of controlling the levitating amount, is required.

10 Conventionally, an aluminum alloy has been used as the material of the substrate for a magnetic disk. However, an aluminum alloy has the problem that it is deformed readily and exhibits an undesirable flatness at the disk surface after polishing on account of insufficient hardness.

15 Furthermore, an aluminum alloy has another problem in that the layer of the magnetic recording medium is readily peeled off when the magnetic disk is contacted mechanically by the head. Therefore, a glass substrate having a smaller deformation, a more preferable flatness and a larger
20 mechanical strength than the aluminum substrate has been developed. The glass substrate can be used also as the substrate for a photomagnetic disk, wherein the substrate itself is required to be transparent.

25 In order to use a glass substrate as the media to record information, chemically strengthened glass, having a mechanical strength which is increased by replacing alkali elements at the surface of the substrate with other alkali

elements, and crystallized glass, wherein fine crystallized particles are deposited in an amorphous glass matrix, have been developed. However, the chemically strengthened glass has a problem in that the alkali ions tend to corrode the magnetic film and deteriorate the adhesive strength of the film during a heating step and a cleaning step in the magnetic film forming process, because of the presence of the alkali substituted layer at the surface of the film. Accordingly, JP-A-7-223845 (1995) has proposed a chemically strengthened glass, which was superior in chemical resistance, prepared by a further chemical treatment after the chemical strengthening.

On the other hand, crystallized glass has a problem in that the irregularity of the surface of the glass substrate after polishing was very large, because of the difference in abrasion resistance between the generated crystalline fine particles and the amorphous glass, so that a desirable flatness of the surface could not be obtained. Therefore, decreasing the levitating amount of the head was difficult for responding. In accordance with JP-A-7-300340 (1995), the flatness was improved by decreasing the particle size of the crystallized fine particles to the range of 5 - 100 nm.

However, the chemical strengthening method disclosed in JP-A-7-223845 (1995) has a problem in that making the characteristics of the substrate homogeneous after the chemical strengthening process and the polishing process in the chemical strengthening treatment is still difficult.

Furthermore, providing an effective intermediate film to prevent a diffusion of alkaline ions between the magnetic film and the glass substrate, which is necessary to prevent the magnetic film from being corroded by the alkaline ions, has not been solved completely yet. In accordance with the crystallizing method disclosed in JP-A-7-300340 (1995), the obtained glass substrate has a low transmittance because the glass is colored to a milky color, and accordingly, the glass substrate is difficult to use as a substrate for optical information recording. Furthermore, the crystallizing method has another problem in that making the characteristics of the substrate homogeneous is difficult, because a fine precise crystallizing process is required.

In either case using the above methods, decreasing the production cost is difficult, because a post-treating process, such as a chemical strengthening process or a crystallizing process, is required.

SUMMARY OF THE INVENTION

One of the objects of the present invention is to provide a glass substrate in the form of a disk for recording information having a preferable mechanical strength, a desirable chemical stability and a sufficient optical transmittance for optical information recording, and which can be manufactured by a short process.

Another object of the present invention is to provide a disk for recording information, which can achieve a high recording density, and to effectively decrease the size and

weight of the disk by using a thin disk having no intermediate film, and a disk recording apparatus using the same.

5 In order to achieve the above objects, the first feature of the present invention relate to an information recording disk comprising a film of a medium for recording information formed on at least one surface of a substrate in the shape of a disk, wherein the substrate is composed of a glass containing at least a rare earth element. The film of
10 the medium for recording information can be formed directly on the surface of the substrate, or it can be formed indirectly on the surface of the substrate via an intermediate film (pre-coated film).

15 In accordance with the above structure, a disk for recording information having a sufficient mechanical strength to accommodate a thinning of the disk, and a desirable chemical stability and preferable homogeneity to avoid the necessity for an intermediate film, can be provided.

20 In accordance with the feature of the first invention, the thermal expansion coefficient of the glass is desirably in the range of $70 - 130 \times 10^{-7}$. The magnetic film is formed on the surface of a disk for recording information, such as a magnetic disk, a photomagnetic disk, and the like. The
25 thermal expansion coefficient of the magnetic film is approximately 100×10^{-7} . Therefore, if the thermal expansion coefficient of the glass is not in the range of

70 - 130 X 10⁻⁷, a stress is applied to the magnetic film in the magnetic film manufacturing process accompanying heat treatment, and the magnetic characteristics can be deteriorated, the magnetic film can be peeled off, or the substrate itself can generate cracks. Therefore, the thermal expansion coefficient is desirably in the above indicated range.

In accordance with the first feature of the invention, fine particles are dispersed in the glass, and the rare earth element is desirably contained in the fine particles. The strength of the glass can be increased by the presence of the fine particles being dispersed in the glass.

The amount of the rare earth element, which can be dissolved into a glass composition having a net structure, has an upper limit (a limit of solid solution). If the rare earth element is added to the in an amount glass exceeding the upper limit, the rare earth element is deposited in the glass matrix as a crystalline phase or an amorphous phase. The particles composed of the above crystalline phase or the amorphous phase are called fine particles. If the deposition of the rare earth element is not homogeneous, the fine particles can be deposited partially by exceeding the upper limit of the solid solution. Therefore, the content of the rare earth element does not necessarily exceed the upper limit of the solid solution in the glass matrix. The rare earth element is desirably contained in both the glass matrix and the fine particles. The fine particles are

desirably crystalline. Whether the fine particles are crystalline or amorphous can be readily determined by observing a lattice fringe image taken by a transmission electron microscope, because lattice stripes can be observed at the crystalline portion, but will not be observed at the amorphous portion.

The strength of the glass is improved by dispersing the fine particles in the glass matrix, because the fine particles have an effect to suppress deformation and breakage of the glass matrix when a stress is applied to the glass matrix. The higher strength improving effect of the dispersed fine particles can be obtained by the fine particles having a smaller particle size and when they are dispersed more uniformly.

In accordance with the first feature of the invention, the glass preferably contains a rare earth element in the range of 0.5 - 15% by weight to the total weight of the glass based on the amount converted to the oxide of Ln_2O_3 (Ln is a rare earth element).

When the content of the rare earth element is less than 0.5% by weight, the effect for improving the mechanical strength is not significant. When the content of the rare earth element exceeds 15% by weight, the size of the fine particles is increased, and the transmittance for white light is decreased. Therefore, an information recording disk having a preferable mechanical strength balanced with a desirable transmittance for white light can be provided by

the composition described above. However, in a case where the information recording disk is used as a fixed type magnetic disk (hard disk), a decrease in the transmittance for white light does not cause a problem. Therefore, a
5 consent of the rare earth element exceeding 15% by weight can be used without causing any problem.

In accordance with the first feature of the invention, the rare earth element is preferably at least any one element selected from a group consisting of Gd, Tb, Dy, Ho,
10 Er, Tm, Yb, and Lu. Any one of the above elements readily forms crystalline fine particles in the glass and has a significant effect for improving the strength.

The average particle size of the fine particles is desirably in the range of 1 - 50 nm. If the average
15 particle size exceeds 50 nm, the volume fraction of the fine particles is increased, and the transmittance for white light is decreased. If the average particle size is less than 1 nm, the effect for improving the strength is not significant.

20 The volume fraction of the fine particles in the glass is desirably, at the utmost, 20%. If the volume fraction of the deposited particles exceeds 20%, the transmittance for white light is undesirably decreased.

In accordance with the first feature of the invention,
25 the glass desirably contains a rare earth element in the range of 0.5 - 15% by weight to the total weight of the glass based on the amount converted to the oxide of Ln_2O_3 ,

and additionally other components such as SiO_2 : 40 - 80% by weight, B_2O_3 : 0 - 20% by weight, R_2O (R is an alkali metal): 5 - 20% by weight, RO (R is an alkali earth metal): 5 - 20% by weight, and Al_2O_3 : 0 - 10% by weight, where the sum of R_2O and RO is in the range of 10 - 30% by weight. The above glass is called soda lime glass. The effect generated by adding the rare earth element is particularly significant with silicates glass wherein both the alkaline element and the alkaline earth element are contained in the glass. A large portion of the added rare earth element is dissolved into the glass matrix as a solid solution, but a part of the rare earth element, which can not be dissolved into the glass matrix, is deposited as crystalline fine particles. The upper limit of dissolving the rare earth element into the glass matrix as a solid solution, that is an index indicating the easiness of depositing, varies depending on the kind of the matrix. As described previously, the strength of the glass is not increased significantly if the fine particles are not deposited sufficiently. When silicates glass containing both the alkaline element and the alkaline earth element by the above composition is used as the matrix, the rare earth element can be deposited adequately, and a glass substrate which satisfies the required strength and chemical stability for the information recording disk can be manufactured.

In accordance with the first feature of the invention, the transmittance of the glass for visible white light is

desirably at least 70%. In order to use the glass substrate for a photodisk, the amount and the particle size of the deposited particles should be controlled so that at least 70% of the transmittance of the glass for the visible white light can be obtained. If the transmittance is less than 70%, the laser beam for recording information onto the recording medium decays during transmission through the glass to cause a decreasing of the S/N ratio, and other problems.

In accordance with the second feature of the present invention, a magnetic disk provided with a film of a magnetic medium for recording information formed on the surface of the substrate in the shape of a disk is provided, wherein the substrate is composed of a glass, the thickness of the substrate is, at the utmost, 0.38 mm, and the film of the magnetic medium for recording information is formed directly on the substrate.

By decreasing the thickness of the substrate, the number of the magnetic disks per volume can be increased. Therefore, if the recording density is the same, a smaller and lighter magnetic disk apparatus than previously available can be provided.

The conventional magnetic disk had a problem in that the magnetic recording medium was corroded by the alkaline element diffused from the glass substrate. Therefore, it was necessary to provide an intermediate layer composed of metallic chromium and other materials between the glass

substrate and the magnetic recording medium. On the other hand, there is very little possibility that the alkaline element in the glass substrate relating to the present invention will diffuse into the magnetic recording medium.

5 Therefore, it is not necessary to provide an intermediate layer, and so the magnetic recording medium can be formed directly onto the substrate. Accordingly, a deterioration of the magnetic characteristics of the magnetic recording medium by influence of the structure and the composition of
10 an intermediate layer can be avoided.

In accordance with the third feature of the present invention, a photomagnetic disk comprising a magnetic recording medium film is provided for recording information, which film is formed on one of the surfaces of a disk-shaped
15 substrate, wherein the substrate is composed of glass, the thickness of the substrate being, at the utmost, 0.38 mm, and the diameter of the substrate being at least 2.5 inches. Generally, a photomagnetic disk has a slight warp caused on the condition of a manufacturing and a variation of the
20 environment during use. Thus, the angle formed by the optical axis of the light head and the disk surface is deviated from a perpendicular direction by several mrad (milliradian) on account of the warp. When the light beam diameter is reduced to increase the storage capacity, the
25 aberration and the birefringence caused by the warp is increased sharply. The aberration can be reduced by reducing the thickness of the disk. Accordingly, a stable

signal can be read out even if the light beam diameter is reduced. In accordance with the glass substrate of the present invention, the thickness of the disk substrate can be reduced from the conventional 0.8 mm to 0.38 mm while
5 retaining the disk diameter of at least 2.5 inches, and the width of allowable error in the manufacturing of the disk can be broadened.

In accordance with the fourth feature of the present invention, a glass substrate in the form of a disk for
10 recording information is provided, comprising a medium film for recording information, which is formed on the surface of a disk-shaped substrate, wherein the substrate is composed of glass containing at least one of the rare earth elements.

In accordance with the above composition, the strength
15 of the substrate can be ensured sufficiently even if the substrate is thin. Therefore, the production yield can be increased and the production cost can be decreased by facilitating the handling of the disk in the manufacturing process. For example, no cracks are generated even if the
20 polishing velocity is increased to a certain level during the surface polishing step after the glass casting, and handling of the substrate in transportation after its manufacture can be facilitated.

In accordance with the fifth feature of the present
25 invention, an information recording disk apparatus is provided, comprising at least an information recording disk, a head for reading out information from the disk or

inputting information to the disk, a driver for the disk, and a driver for the head, wherein the information recording disk is the information recording disk described above in connection with the present invention.

5 In accordance with the above composition, an information recording disk apparatus having a large capacity can be provided at a low price because its production cost is low.

BRIEF DESCRIPTION OF THE DRAWINGS

10 These and other objects, features and advantages of the present invention will be understood more clearly from the following detailed description with reference to the accompanying drawings, wherein:

Fig. 1 is a graph indicating a relationship between the
15 additive amount of Er_2O_3 , Al_2O_3 , and Si_2O_4 and variation in micro-dickers hardness,

Fig. 2 is a graph indicating a relationship between the additive amount of Er_2O_3 , Al_2O_3 , and Si_2O_4 and variation in thermal expansion coefficient,

20 Fig. 2 is a graph indicating a relationship between the additive amount of Er_2O_3 , Al_2O_3 , and Si_2O_4 and the variation in thermal expansion coefficient;

Fig. 3 is a graph indicating a relationship between the additive amount of Er_2O_3 and the variation in the average
25 particle size of the deposited crystalline fine particles;

Fig. 4 is a graph indicating a relationship between the additive amount of Er_2O_3 and the variation in the

transmittance for white light;

Fig. 5 is a graph indicating a relationship between the additive amount of oxides of rare earth element and the variation in the micro-Vickers hardness;

5 Fig. 6 is a graph indicating a relationship between the additive amount of oxides of rare earth element and the variation in the glass transition temperature;

Fig. 7 is a graph indicating a relationship between the hardness (Hv) of the substrate and the defect fraction;

10 Fig. 8 is a diagrammatic cross section indicating the film composition of the magnetic disk substrate manufactured by the present invention;

Fig. 9 is a diagrammatic cross section indicating the film composition of the magnetic disk substrate manufactured by another embodiment of the present invention; and

Fig. 10 is a perspective view of the magnetic disk apparatus manufactured by the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Embodiment 1)

20 Hereinafter, details of the present invention will be explained with reference to various embodiments.

In Table 1, the mixing ratio (by weight ratio) of the glass raw materials, the glass transition temperature ($T_g/^\circ\text{C}$), the thermal expansion coefficient ($\alpha \times 10^{-7}/^\circ\text{C}$), and

25 micro-Vickers hardness (Hv) considered in accordance with the present invention are indicated.

Table 1

No.	Mixing Ratio (by weight)						
	SiO ₂	CaO	Al ₂ O ₃	MgO	B ₂ O ₃	BaO	SrO
1	72.5	8.0	1.4	4.1	-	-	-
2	72.5	8.0	1.4	4.1	-	-	-
3	72.5	8.0	1.4	4.1	-	-	-
4	72.5	8.0	1.4	4.1	-	-	-
5	72.5	8.0	1.4	4.1	-	-	-
6	72.5	8.0	1.4	4.1	-	-	-
7	72.5	8.0	1.4	4.1	-	-	-
8	72.5	8.0	1.4	4.1	-	-	-
9	72.5	8.0	1.4	4.1	-	-	-
10	75.9	8.0	1.4	4.1	-	-	-
11	79.5	8.0	1.4	4.1	-	-	-
12	72.5	8.0	4.4	4.1	-	-	-
13	72.5	8.0	8.4	4.1	-	-	-
14	67.8	-	14.5	-	-	-	-
15	50.0	6.0	16.5	7.0	-	-	-
16	40.0	10.0	17.0	10.0	-	-	-
17	72.5	8.0	1.4	4.1	7.0	-	-
18	72.5	8.0	1.4	4.1	-	15.2	-
19	72.5	8.0	1.4	4.1	-	-	10.3
20	67.8	-	14.5	-	-	-	-
21	50.0	6.0	16.5	7.0	-	-	-
22	40.0	10.0	17.0	10.0	-	-	-
23	72.5	8.0	1.4	4.1	7.0	-	-
24	72.5	8.0	1.4	4.1	-	15.2	-
25	72.5	8.0	1.4	4.1	-	-	10.3

Table 1 (continued)

No.	Mixing ratio (by weight)				T _g (°C)	α	Hv
	TiO ₂	ZnO	Na ₂ O	Er ₂ O ₃			
1	-	-	14.0	0.0	556	85.0	615
2	-	-	14.0	1.0	560	88.6	621
3	-	-	14.0	2.0	556	90.2	635
4	-	-	14.0	5.0	585	91.3	673
5	-	-	14.0	10.0	582	92.2	683
6	-	-	14.0	15.0	590	93.0	707
7	-	-	14.0	16.0	598	93.5	712
8	-	-	14.0	21.0	608	93.8	722
9	-	-	14.0	32.0	-	-	-
10	-	-	14.0	0.0	563	85.4	613
11	-	-	14.0	0.0	570	87.0	617
12	-	-	14.0	0.0	572	90.3	627
13	-	-	14.0	0.0	583	90.6	642
14	-	-	17.7	10.0	530	96.6	792
15	6.5	14.0	-	10.0	545	110.0	720
16	7.0	16.0	-	16.0	520	126.5	706
17	-	-	7.0	5.0	594	59.5	721
18	-	-	7.0	5.0	605	76.9	686
19	-	-	7.0	5.0	617	76.0	685
20	-	-	17.7	-	520	85.4	735
21	6.5	14.0	-	-	521	103.0	652
22	7.0	16.0	-	-	502	122.4	634
23	-	-	7.0	-	594	57.0	710
24	-	-	7.0	-	588	77.9	644
25	-	-	7.0	-	597	72.0	597

The glass transition temperature and the thermal expansion coefficient were determined from thermal expansion curves of the glass. The thermal expansion coefficient was

calculated from the elongation rate of the glass from 50°C to 500°C. The temperature elevating velocity was 5°C/minute, and the loaded weight was 10 g. A quartz glass (thermal expansion coefficient; $5 \times 10^{-7}/^{\circ}\text{C}$) was used as a standard sample. The size of the test pieces was 5 mm in diameter and 20 mm in height. The micro-Vickers hardness (Hv) was determined as an average value of ten points measured under the condition of the loaded weight of 100 g, and the weight loading time of 15 seconds.

The glass was prepared in the manner described hereinafter. A mixture of respective predetermined amounts of powder of the raw materials was put into a crucible made of platinum, and was melted at 1600°C in an electric furnace. After melting the raw materials completely, the molten glass was stirred for one hour with a platinum stirring blade. Then, the stirring blade was taken out from the molten glass, the molten glass was allowed to stand still for 30 minutes, and a glass block was obtained by pouring the molten glass into a die made of graphite, which had been treated to approximately 300°C, and then the die was cooled rapidly. Subsequently, strain relief annealing was performed by reheating the glass block to a temperature near the glass transition temperature of the respective glass, and the glass block was then gradually cooled with a cooling velocity of 1 - 2°C/minute.

The glass of No. 1 in Table 1 contains silicon oxide as a main component. Taking this glass as a standard glass

having a fundamental composition, various rare earth elements were added to the standard glass of 100 parts by weight. Erbium oxide (Er_2O_3), i.e. one of the rare earth elements, was added to the glasses of No. 2 - 8 in Table 1 respectively within the range of 1 - 21% by weight. The glass of No. 9 contained erbium oxide of 32% by weight. However, a part of the raw erbium oxide powder remained in the molten glass undissolved, and homogenous glass could not be obtained. The glasses of No. 10, 11, 12, and 13 were prepared by adding SiO_2 and Al_2O_3 increasingly to 100 parts by weight of the No. 1 glass.

The glass of No. 14 contained a further increased amount of Al_2O_3 , and erbium oxide of 10% by weight. The glasses of No. 15 and 16 contained a more increased amount of Al_2O_3 , and a more decreased amount of SiO_2 than the glass of No. 14. Furthermore, ZnO and TiO_2 were added as crystallizing components in addition to erbium oxide of 10% by weight.

The glass of No. 17 contained a half amount of Na_2O of the glass of No. 1, and B_2O_3 in addition to erbium oxide of 5% by weight. The glasses of No. 18 and 19 contained a half amount of Na_2O of the glass of No. 1, and additionally an alkaline earth metal oxide such as BaO , SrO , and the like. The glasses of No. 20 - 23 were the same glasses as No. 15 - 19 except no erbium oxide was contained.

As a comparative example, the T_g , α , and H_v of a glass, which was chemically strengthened by alkali replacement of

the glass of No. 1, are indicated in Table 2.

Table 2

No.	Tg (°C)	α	Hv	Remarks
26	557	85	670	Chemically strengthened glass

5 The chemically strengthened procedure was performed by
immersing the glass, manufactured in a flat plate of
approximately 0.63 mm thickness, into a molten potassium
nitrate bath at 380°C for 40 minutes. The thickness of the
chemically strengthened layer was approximately 20 μ m. The
10 Hv of the chemically strengthened glass was 670. In
comparison with the Hv of 615 of the glass before the
chemical strengthening, it was revealed that the Hv was
increased approximately 9% by the chemical strengthening.
The thermal expansion coefficient was not increased by the
15 chemical strengthening. The glass transition temperature
was increased somewhat by the chemical strengthening.

On the basis of the Hv of the chemically strengthened
glass, the strength of the glasses indicated in Table 1 was
evaluated. When the additive amounts of Er_2O_3 were 1.0% and
20 2.0%, respectively, by weight (No. 2, and 3), each of the
micro-Vickers harnesses of the glasses was increased to 621
and 635 in comparison with the glass of No. 1. However, the
increased amount was not significant, and the hardness did
not reach the hardness of the chemically strengthened glass.
25 When the additive amount of Er_2O_3 was 5.0% by weight (No. 4),
the micro-Vickers hardness of the glass was increased to
673, exceeding the Hv of the chemically strengthened glass.

In accordance with the glasses of No. 5 - 8, wherein the additive amount of Er_2O_3 was increased further to 10 - 21% by weight, the micro-Vickers hardness of the glass were increased further, such as to 683, 707, 712, and 722, respectively.

Fig. 1 indicates a relationship between the additive amount of Er_2O_3 , Al_2O_3 , and Si_2O_4 and the variation in the micro-Vickers hardness. The additive amount indicated by the abscissa is expressed by mol% of oxide containing two cations. That means, for example, SiO_2 is expressed as Si_2O_4 , and Er_2O_3 and Al_2O_3 are expressed as Er_2O_3 and Al_2O_3 with no change. In accordance with Fig. 1, the Hv of the Er_2O_3 added glass is increased linearly in relation to the additive amount of Er_2O_3 . The Hv of the glass exceeds the Hv of the chemically strengthened glass by adding Er_2O_3 of at least 0.013 mol% (50% by weight).

On the other hand, although an increasing tendency of the Hv can be observed with the glasses (No. 8 - 11), in which Si_2O_4 , or Al_2O_3 has been added, the increased amount is not significant, and the Hv does not reach the level of the chemically strengthened glass even if the additive amount of Si_2O_4 , or Al_2O_3 exceeds 0.05 mol%.

Fig. 2 indicates a relationship between the additive amount of various oxides and the variation in the thermal expansion coefficient. The thermal expansion coefficient of the Er_2O_3 added glass is increased in accordance with the increasing additive amount of Er_2O_3 . Because of the large

thermal expansion coefficient of the information recording medium layer, matching of the substrate with the information recording medium layer has been improved by increasing the thermal expansion coefficient of the substrate.

5 The Hv of the substrate could be increased significantly by adding Er_2O_3 . However, the increase in Hv was scarcely observed when the additive amount of Er_2O_3 was less than 0.5% by weight, in addition to the embodiments indicated in Table 1. Therefore, Er_2O_3 is preferably added
10 at least 0.5% by weight. On the contrary, when Er_2O_3 was added more than 30% by weight, the Er_2O_3 was not dissolved completely, and the obtained glass was not homogeneous. Therefore, the additive amount of Er_2O_3 is desirably, at the utmost, 30% by weight. The effect of adding Er_2O_3 in
15 increasing the Hv and the Tg was compared with the same effect of adding each of SiO_2 and Al_2O_3 , which were regarded as components to increase the mechanical strength, and it was found that the increase in the Tg was almost the same, but the addition of Er_2O_3 was more effective in increasing
20 the Hv. The Hv of the glasses of No. 14 - 16, to which an increased amount of Al_2O_3 was added, respectively, were improved in comparison with the glasses of No. 20 - 22, to which no Er_2O_3 was added. The glasses of No. 15 and 16 became opaque in a heat treatment at 900°C , because
25 crystalline particles were deposited in the glass. The Hv were measured under the above condition, and it was found that the Hv were increased, such as to 760 and 720,

respectively, in comparison with the Hv before the heat treatment.

The contents of Na_2O in the glasses of No. 17 - 19 were decreased to a half of the glass of No. 1. Therefore, an elevation of the characteristic temperature was expected, and a predetermined amount of respective one of B_2O_3 , BaO , and SrO , which were regarded as components to decrease the melting point, was added to the glasses of No. 17 - 19. Furthermore, Er_2O_3 of 5% by weight was added to each of the glasses of No. 17 - 19. The Hv of all the glasses of No. 17 - 19 were improved in comparison with the glasses of No. 23 - 25, to which no Er_2O_3 was added.

A three point bending strength test was performed on the glasses of No. 1 and 5, and the chemically strengthened glass (No. 12) for comparison. Average values of the three point bending strength (σ/Mpa) are indicated in Table 3.

Table 3

No.	n	σ (Mpa)
1	20	328
5	20	391
26	20	390

The test was performed using glass test pieces 0.63 mm thick, 2 mm wide, and 3 mm long. The bottom span was 1.2 mm. The number of the test pieces (n) was 20 for all the glasses. The three point bending strength σ (Mpa) is expressed by the following equation:

$$\sigma (312/2at^2)$$

where, w : loaded weight

l : bottom span

a : width of the test piece

5 t : thickness of the test piece

The average three point bending strength of the glass of No. 1 was 328 MPa. The average three point bending strength of the glass of No. 5, which contained Er_2O_3 of 10.0% by weight, was 391 MPa, which represents an increase
10 by approximately 19% from the glass of No. 1, and an equivalent strength to the chemically strengthened glass (No. 26) was obtained.

In order to study the mechanism of mechanical strength increment by adding rare earth element oxides,
15 microstructures of the glasses of No. 1 - 8 and 10 were observed by a transmission electron microscope.

The glasses of No. 1 and 10, which contained no rare earth element oxides, were in a homogeneous amorphous condition. On the other hand, the glasses of No. 2 - 8 were
20 in a condition wherein fine particles having a nano-order particle size were dispersed in an amorphous glass matrix. Based on the observation of high resolution images, the fine particles were determined as crystalline particles. As explained above, fine particles were observed in the glasses
25 containing the rare earth element oxides, and the degree of improvement in the mechanical strength of these glasses was significant. The fine particles were not observed in the

glass containing Al_2O_3 and others such as the glass of No. 10, and the degree of improvement in the mechanical strength of the glass was not significant. Therefore, it was concluded that the mechanical strength was increased based on the presence of the fine particles.

The particle sizes of the fine particles were different each from the others depending on the content of Er_2O_3 . The average diameters of the fine particles generated in respective ones of the glasses and the transmittance for white light are indicated in Table 4.

Table 4.

No.	2	3	4	5	6	7	8
Er_2O_3 content (weight ratio)	1.0	2.0	5.0	10.0	15.0	16.0	21.0
Average diameter (nm)	1	3	8	15	38	51	103
Transmittance (%)	91	85	79	74	70	67	58

Fig. 3 indicates a relationship between the average particle size of the fine crystalline particles and the Er_2O_3 content, and Fig. 4 indicates a relationship between the transmittance of the glass and the Er_2O_3 content. The average particle size was increased in proportion to approximately a square of the Er_2O_3 content. The transmittance was decreased in negative proportion to the Er_2O_3 content.

The relationship between the efficiency of recording

information and the transmittance of light was studied. Then, it was found that the recording of information was performed with a high efficiency when the transmittance for white light was at least 60%, and the recording of information was not performed efficiently when the transmittance for white light was less than 60%. Therefore, the transmittance for white light is desirably at least 60%. The average diameter of the glass of No. 16 was 51 nm, and the volume fraction of the fine particles calculated from the TEM photograph was 22%. On the basis of the above data, the volume fraction of the fine particles is increased and the transmittance for white light is decreased if the average diameter exceeds 50 nm. Therefore, it is not desirable if the Er_2O_3 content exceeds 16% by weight, the average diameter of the deposited particles exceeds 50 nm, and the volume fraction of the deposited particles exceeds 20%.

Various rare earth elements were added to the glass of No. 1 for studying their influence. Table 5 indicates the kind of added rare earth element, as well as the glass transition temperature (T_g), the thermal expansion coefficient and micro-Vickers hardness (H_v) of the obtained glasses. Figs. 5 and 6 indicate relationships between the kind of added rare earth elements and H_v and T_g , respectively. Each of the rare earth elements was added as an oxide expressed by the chemical formula of Ln_2O_3 . The additive amount of all the rare earth elements was 0.026

mol%. The manufacturing method of the glass and the method of measuring the characteristics are the same as indicated in Table 1.

Table 5

No.		Ln ₂ O ₃ content	Tg (°C)	α	Hv
	Ln	(weight ratio)			
27	Sc	3.58	593	91.4	666
28	Y	5.89	582	81.6	653
29	La	8.47	583	90.2	650
30	Ce	8.53	582	91.3	648
31	Pr	8.61	585	92.2	651
32	Nd	8.78	587	86.4	646
33	Sm	9.07	583	93.5	651
34	Eu	9.19	585	95.5	652
35	Gd	9.46	580	90.9	685
36	Tb	9.51	583	90.3	682
37	Dy	9.70	581	90.6	683
38	Ho	9.82	584	91.6	682
39	Er	10.00	582	92.2	683
40	Tm	10.03	586	92.0	682
41	Yb	10.30	588	90.9	685
42	Lu	10.40	585	91.1	684

In accordance with Table 5, the micro-Vickers hardness was increased in all the cases when any rare earth element was added. The amount of the increment was significant when a heavier rare earth element than Gd₂O₃, so-called heavy rare earth elements, was added. The hardness when a heavy rare earth element was added at least 680, which was larger than the value of Hv of the chemically strengthened glass. On the other hand, the hardness when the light rare earth

element from Sc_2O_3 to Eu_2O_3 was added was approximately 650, which was smaller than the value of H_v of the chemically strengthened glass.

5 The glass transition temperature was constant, such as approximately 585, regardless which rare earth element was added. The thermal expansion coefficient of the glasses were in the range of $81.6 - 92.2 \times 10^{-7}/^\circ\text{C}$, and the matching of the substrate with the information recording medium layer was preferable. In accordance with the study
10 described above, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu are the desirable rare earth elements to be added to the glass.

When the structure of the glass of No. 21 containing Gd_2O_3 was observed by a TEM, crystalline fine particles the same as in the Er_2O_3 added glass were observed. The average
15 particle size was 15 nm.

The composition of the base glass was studied. A content of SiO_2 less than 40% by weight was not desirable, because the mechanical strength and chemical stability of the base glass were deteriorated. When the content of SiO_2
20 exceeds 80% by weight, the fusibility of the glass was decreased, and many striae were generated. The thermal expansion coefficient of the glass was decreased such a small level that the glass became inadequate to be used as a glass for the substrate. For the above reason, the content
25 of SiO_2 should be desirably in the range of 40% by weight - 80% by weight.

When B_2O_3 was added to the base glass, a base glass

having a superior fluidity and an adequate thermal expansion coefficient was obtained. However, when the content of B_2O_3 exceeded 20% by weight, the effect of improving the mechanical strength by adding the rare earth elements was decreased. Therefore, the content of B_2O_3 is desirably, at the utmost, 20% by weight.

Alkali metal oxides were studied. When sum of the additive amount of the alkali metal oxides (Li_2O , Na_2O , K_2O) exceeded 20% by weight, the chemical stability was decreased. Therefore, the sum of the content of the alkali metal oxides should be desirably in the range of 0 - 20% by weight. Furthermore, when the sum of the additive amount of the alkali earth metal oxides exceeded 20% by weight, the chemical stability was decreased as in the case of adding alkali metal oxides. Therefore, the sum of the content of the alkali earth metal oxides should be desirably in the range of 0 - 20% by weight.

Adding each of the alkali metal oxides, alkali earth metal oxides, and B_2O_3 has the same effect in decreasing the melting point of the glass. However, when the sum of the additive amount of the above oxides was less than 10% by weight, the fluidity was undesirable, and many striae were generated. On the contrary, when the sum exceeded 30% by weight, the chemical stability was decreased. Therefore, the sum of the additive amount of the alkali metal oxides, alkali earth metal oxides, and B_2O_3 should be desirably in the range of 10 - 30% by weight.

Adding Al_2O_3 was effective in increasing the mechanical strength and chemical stability of the glass. However, the content of Al_2O_3 exceeding 17% by weight was undesirable, because the fluidity of the glass was decreased. Therefore, the content of Al_2O_3 should be desirably, at the utmost, 17% by weight.

When the content of the rare earth oxides exceeded 30% by weight, homogeneous glass was hardly obtained, because raw material powder remained in the glass after the melting operation of the glass, and the content was undesirable. The smaller the sum of the content of the alkali metal oxides, the more significant will be the effect of improving the mechanical strength by adding the less amount of rare earth oxides. When the sum of the additive amounts of the alkali metal oxides and the alkali earth metal oxides was 10% by weight, an improvement in mechanical strength was observed by adding the rare earth oxides of 0.5% by weight. However, when the added amount of the rare earth oxides was less than 0.5% by weight, the effect of improving the mechanical strength was not significant. Therefore, the content of the rare earth oxides should be desirably in the range of 0.5 - 30% by weight.

The glass substrate relating to the present invention can be given a sufficient strength by adding the rare earth elements. Therefore, the chemical strengthening of the glass, which has been necessary for the conventional glass substrate, becomes unnecessary. That means, the glass

substrate of the present invention is characterized in having no compressive strengthening layer which generates a residual stress at the surface of the glass. The presence of the compressive strengthening layer at the surface of the glass can be determined by a method, for example, wherein a laser beam is projected onto the surface of the glass and the reflected beam is spectroscopically analyzed using a prism. Using the above method, it was confirmed for the glass substrate of the present invention that a difference in the residual stresses between the inside of the glass substrate and the surface of the glass substrate hardly existed, in other words, no surface compressive strengthening layer existed.

The practical substrates were prepared actually with the glass obtained by the embodiments, and their characteristics were evaluated. The glasses of No. 1, 5, 7, 8, 18, and 35 were used. As the comparative examples, the chemically strengthened glass of No. 26, and SiO_2 - Al_2O_3 - ZnO - MgO - RO group crystallized glass substrate indicated in Table 6 were evaluated.

The shape of the prepared glass substrate was 65 mm in diameter and 0.635 mm in thickness. The water resistance, heat resistance, surface roughness, and transmittance for white light of the prepared substrates are indicated in Table 7.

Table 6

No.	Tg (°C)	α	Hv	Remarks
43	780	114	720	Crystallized glass

Table 7

No.	Water Resistance Alkaline concentration (ppm)	Heat resistance	Surface roughness Ra (Å)	Transmittance (%)
5	15.0	○	4	74.0
35	15.0	○	4	94.0
26	312.0	△	4	95.0
43	2.0	○	4	15.0
1	11.0	○	4	94.0
7	11.5	○	5	67.0
8	10.7	○	10	58.0
18	4.0	○	5	79.0

The water resistance was evaluated by immersing the substrate into warm pure water of 80 ml at 70°C for 20 hours, determining the amounts of total alkali elements and alkaline earth elements which dissolved into the pure water, and indicating the total dissolved amount by ppm.

The heat resistance was evaluated by heating the substrate to 350°C in a vacuum, and subsequently analyzing the surface portion of the substrate by secondary ion mass spectrometry. The test piece, wherein a diffusion of the alkaline ions was observed at the surface layer of the substrate, was indicated by △, and the test piece, wherein the diffusion was not observed, was indicated by ○.

The surface roughness was evaluated by an average surface roughness R_a (\AA) using a surface roughness tester. The transmittance was evaluated as an intensity ratio of incident light and transmitted light by irradiating the surface of the substrate with a white light source.

The water resistance of the glass substrates of No. 1, 5, 7, 8, 18, 35, and 43 were desirable, because the dissolved amounts of the alkaline elements were small. The chemically strengthened glass substrate of No. 26 was not desirable, because the dissolved amounts of the alkaline elements was significant.

Similarly in the treat resistance evaluation, a large amount of alkaline elements were detected at the surface layer of the chemically strengthened glass substrate of No. 26, and it was found that movement of the ions occurred. As explained above, the chemically strengthened glass substrate was unstable because it readily caused movement of the alkaline elements. On the contrary, the glass substrate of the present invention was desirable in both thermal and chemical stability.

Regarding the surface roughness, preferable flatness such as $R_a = 4 - 5 \text{ \AA}$ was obtained with the glass substrates of No. 1, 7, 18, 5, 35, and 26. On the contrary, the surface roughness of the glass substrates of No. 8 and 43 were as large as $R_a = 9 - 10 \text{ \AA}$.

The transmittance for white light of the glasses of No. 1, 7, 5, 18, 35, and 26 were as desirable as 67 - 95%. The

transmittance of the glasses of No. 8 and 43 were as low as 58% and 15%, respectively.

A relationship between the surface roughness and the depositing condition of the fine particles was studied.

5 Regarding the glass of No. 7, the content of Er_2O_3 was 16% by weight, and the average particle size of the deposited fine particles was 51 nm. The volume fraction of the fine particles was 40%. The transmittance of the glass of No. 7 under the above condition was 67%. On the other hand,
10 regarding the glass of No. 8, the content of Er_2O_3 was 21% by weight, the average particle size of the deposited fine particles was 103 nm, and the volume fraction of the fine particles was 72%. The transmittance of the glass of No. 8 under the above condition was 58%. Under the above
15 conditions, the surface roughness of the glass of No. 7 was 5.0 Å, and the glass of No. 8 was 10.0 Å, twice that of the glass of No. 7. As explained above, it was found that when the content of Er_2O_3 exceeded 20% by weight, the average particle size of the deposited fine particles exceeded 100
20 nm, and the transmittance was less than 60%, the surface roughness of the glass was significant, and the glass was inferior in surface flatness.

In accordance with the above findings, the content of rare earth oxides such as Er_2O_3 is desirably less than 20% by
25 weight. The average particle size is desirably, at the utmost, 100 nm. The transmittance is desirably at least 60%. When the above conditions are satisfied, a

sufficiently small surface roughness can be obtained.

Using each of the above 8 kinds of glasses, a magnetic disk was manufactured by forming a magnetic film on the glass substrate, and its characteristics were evaluated.

5 The composition of the film of the manufactured magnetic disk is indicated in Fig. 8. In Fig. 8, the numeral 1 indicates the glass substrate, 2 denotes a Cr precoat film, 3 denotes a Cr base film, 4 denotes a Co-Cr group magnetic film, 5 denotes a C protective film, 6 denotes an etching
10 texture, and 7 denotes a lubricating film.

After cleaning a magnetic glass substrate 65 mm in diameter, each of the Cr precoat film of 25 nm thickness, the Cr base film of 50 nm thickness, and the Co-Cr group magnetic film of 50 nm thickness was formed on the magnetic
15 glass substrate. Then, after forming the carbon protective film of 10 nm thickness, an etching texture was provided. After performing tape cleaning, a magnetic disk was manufactured by applying the lubricating film 4. The film was formed on both surfaces of the substrate plane.
20 Subsequently, corroded conditions of the magnetic film of the magnetic disk by an alkali and the presence of film splitting were evaluated.

Using the above magnetic disk, a magnetic disk apparatus was manufactured. A schematic perspective view of
25 the manufactured magnetic disk apparatus is indicated in Fig. 10. In Fig. 10, the numeral 8 indicates the magnetic disk indicated in Fig. 8, 9 denotes a rotary shaft, 10

denotes a spindle motor, 11 denotes a magnetic head, 12 denotes a rotary shaft of the magnetic head, and 13 denotes an output terminal of the electrical system. Six magnetic disks 8 were fixed to the rotary shaft 9 in the apparatus. Two magnetic heads 11 were provided at each of the surfaces of the substrate. The magnetic disk apparatus was manufactured by connecting a control system thereto. The levitating amount of the head during rotation of the magnetic disk was 40 nm.

Using the above magnetic disk apparatus, the record regenerating characteristics were evaluated. The observed results concerning alkali corrosion, film splitting, and record regenerating characteristics are indicated in Table 8.

Table 8

No.	Alkali corrosion	Film splitting	Record regenerating characteristics
5	○	○	○
21	○	○	○
12	△	△	△
29	○	○	△

When a ratio of the number of the magnetic disk wherein the alkali corrosion was observed was less than 5% to the total number of the obtained magnetic disks, the alkali corrosion was indicated by ○, and when the ratio was 5% or more, the alkali corrosion was indicated by △. The magnetic disk relating to the present invention scarcely had any alkali corrosion and/or film splitting, and the record

regenerating characteristics of the magnetic disk were preferable.

The alkali corrosion and the film splitting of the chemically strengthened glass of No. 12 were significant, and the glass was undesirable. The alkali corrosion and the film splitting of the crystallized glass of No. 29 were not observed, but the record regenerating characteristics of the glass was undesirable.

Using various kinds of glass relating to the present invention, glass substrates were prepared, and a shock resistance test was performed. The shock resistance was evaluated using magnetic disks, which had the same film structure as indicated in Fig. 8, and were manufactured by forming the magnetic film, the protective film, and others onto both surfaces of the glass substrate in accordance with the same method as described above.

The test was performed by cramping the prepared disk with a jig, and causing a dummy head to impact with the disk using an accelerator. The test was performed at 30 points for each of the various kind of magnetic disks, and the shock resistance was evaluated by the frequency of the points wherein any defects such as cracks, breakage, and the like were generated. As the glass for the substrate, the glasses of No. 1 - 5, 14, 18, 23 - 26, and 43 in Table 1 were used. The results of the shock resistance test are indicated in Fig. 7. The abscissa indicates the Hv of the respective glass, and the ordinate indicates the frequency

of generation of defects in the test by %. A hardness of the glass of 670 can be regarded as a boundary for the generation of defects. When the hardness of the glass is lower than 670, the generation of defects was observed, and the frequency of generation of defects was increased in accordance with decreasing hardness. When the hardness of the glass is higher than 670, the generation of defects was not observed. In accordance with the above observation, if the hardness of the glass substrate is at least 670, a magnetic disk having a sufficient shock resistance against the magnitude of shock employed in the resistance test can be manufactured.

In the same manner, optical disks and an optical disk apparatus were manufactured. Using the glass substrates of the present invention, the optical disk, of which the recording medium layers were scarcely split, could be manufactured, and the record was regenerated with a high efficiency.

As explained above, the information recording disk of the present invention was superior in chemical stability, and defects such as film splitting were scarcely generated. The record regenerating characteristics of the information recording disk apparatus was preferable. The disk and the apparatus could be manufactured with a low cost, because no chemical strengthening treatment or crystallizing treatment was performed.

(Embodiment 2)

A magnetic disk of the shape indicated in Fig. 9 was manufactured using the glass substrate of the present invention. The thickness of the substrate was 0.38 mm. The glass of No. 5, which was not treated for chemical strengthening, was used in manufacturing the magnetic disk. The precoat film, which was generally formed in a routine operation, was not formed, and the magnetic thin film was formed directly onto the surface of the glass substrate. The surface roughness of the glass substrate $R_a = 4.0 \text{ \AA}$.

As comparative examples, magnetic disks were manufactured using soda lime glass strengthened by alkali strengthening treatment, normal soda lime glass without the alkali strengthening treatment, and crystallized glass, as the substrates.

The results of evaluating the strength, flatness, alkali corrosion of the magnetic film, and magnetic characteristics of the magnetic disks are indicated in Table 9. Preferable characteristics are indicated by \bigcirc , and characteristics which are not preferable are indicated by Δ .

Table 9

Substrate	Strength	Flatness	corrosion ¹⁾	Magnetic characteristics	Remarks
No. 5 glass	○	○	○	○	Embodiment
Chemically strengthened soda lime glass	○	○	△	△	Comparative example
Soda lime glass without chemical strengthening	△	○	○	○	Comparative example
Crystallized glass	○	△	○	△	Comparative example

1): Alkali corrosion of the magnetic film

The magnetic disk of the present invention had a desirable strength, and the thickness of 0.380 mm gave it a sufficient strength for practical use. The flatness was also preferable. Corrosion of the magnetic film was not observed, and the magnetic film was not deteriorated even if no precoat film was formed. The levitating amount of the magnetic head could be set as, at the utmost, 30 nm, because the flatness of the disk is preferable, and the magnetic characteristics were also superior.

The soda lime glass treated for chemical strengthening obtained a high mechanical strength. However, the magnetic film was corroded with the alkaline component of the glass, because no precoat film was formed, and, as a result,

deposition of the alkaline components onto the surface of the levitating plane of the magnetic head, after performing a practical sliding test, was frequently observed.

Furthermore, after the sliding test, splitting of the
5 magnetic film was observed. Even for the magnetic disk, which did not cause any defects, its magnetic characteristics were generally deteriorated. The magnetic disk manufactured using the soda lime glass without a chemical strengthening treatment did not have a sufficient
10 strength for practical use. The crystallized glass had a large surface roughness, and the levitating amount of the magnetic head was too large to obtain preferable magnetic characteristics, because the flatness was undesirable.